REMARKS

Claims 1-18 are pending. By this Amendment, claims 1, 8, 9, 15, 17 and 18 are amended. Claims 1, 8, 17 and 18 are amended to recite features supported in the specification on page 18, line 6 – page 19, line 10 and Fig. 2. No new matter is added by any of these amendments.

Applicants appreciate the courtesies extended to Applicants' representative, Mr. Cho, by Examiners Le and Barlow during the March 27, 2004 interview. In accordance with MPEP §713.04, the points discussed during the interview are incorporated in the remarks below and constitute Applicants' record of the interview.

Reconsideration based on the following remarks is respectfully requested.

I.   Amendment Entry after Final Rejection

The foregoing amendments do not raise any new issues after Final Rejection. Therefore, entry of the amendments is proper under 37 CFR §1.116 because the amendments place the application in condition for allowance. Accordingly, Applicants respectfully request entry of this Amendment.

II.   Request for Acknowledgement that References are Considered of Record

An Information Disclosure Statement with form PTO-1449 was filed on August 23, 2001. Applicants have not yet received back a copy of the form PTO-1449 initialed to acknowledge the fact that the Examiner has considered the cited disclosed information.

The Examiner is requested to initial and return to the undersigned a copy of the subject form PTO-1449. For the convenience of the Examiner, copies of that form and the PTO stamped receipt are attached.

III.   Applicants Provide Background Information

Applicants provide, as an attachment, a translation of EP 1 014 054 A2 for the Examiner's consideration. The translation corresponds to the second reference submitted with the October 18, 2001 Information Disclosure Statement.

Applicants also provide, as an attachment, a copy of a non-prior-art paper by Venkatasubramanian *et al.*, as discussed below.

IV.   The Drawings Satisfy All Formal Requirements

The Office Action objects to the drawings filed July 5, 2001 based on informalities. Applicants respectfully submit that Figures 1-10 were replaced with formal drawings in the February 3, 2004 Letter to the Official Draftsperson. Withdrawal of the objection to the drawings is respectfully requested.

V.   Claims 1-18 Define Patentable Subject Matter

The Final Office Action rejects claims 1-18 under 35 U.S.C. §102(b) over "Application of a neural network in gas turbine control sensor fault detection", to Simani *et al.*, ©1998 IEEE, *Proceedings of the 1998 IEEE International Conference on Control Applications*, pp. 182-186 (hereinafter "Simani"). This rejection is respectfully traversed.

Simani does not teach or suggest a method for monitoring the health of a system, which includes performing at each of a plurality of times constructing a condition signature for a present time from a plurality of condition indicators including (a) a plurality of vibration measurements acquired from the system or (b) one or more vibration measurements and one or more performance parameter measurements acquired from the system; predicting a normal signature from a model defining one or more inter-dependencies between condition indicators used to construct the condition signature for a previous time, the normal signature corresponding to a condition signature for a healthy system at the present time; comparing the condition signature for the present time with the normal signature; and registering an event if the condition signature for the present time differs from the normal signature by more than a predetermined threshold, as recited in claim 1.

Simani also does not teach or suggest a method for monitoring the health of a system, which includes performing at each of a plurality of times defining successive intervals of at most 1-sec duration constructing a condition signature for a present time from a plurality of

condition indicators including (a) a plurality of vibration measurements acquired from the system or (b) one or more vibration measurements and one or more performance parameter measurements acquired from the system, predicting, from condition indicators used to construct the condition signature for a previous time, a normal signature corresponding to a condition signature for a healthy system at the present time; comparing the condition signature for the present time with the normal signature; and registering an event if the condition signature for the present time differs from the normal signature by more than a predetermined threshold, as recited in claim 8.

Simani similarly does not teach or suggest a data processing system for monitoring the health of a system, including data acquisition means for acquiring a plurality of condition indicators from the system at each of a plurality of times, the condition indicators including (a) a plurality of vibration measurements or (b) one or more vibration measurements and one or more performance parameter measurements, processor means for constructing a condition signature for a present time from the condition indicators and for predicting a normal signature corresponding to a condition signature for a healthy system at the present time, the normal signature being predicted by a model which defines one or more inter-dependencies between condition indicators used to construct the condition signature for a previous time, comparator means for comparing the condition signature for the present time with the normal signature; and registration means for registering an event if the comparator for the present time indicates that the condition signature differs from the normal signature by more than a predetermined threshold, as recited in claim 17.

Simani further does not teach or suggest a data processing system for monitoring the health of a system, including data acquisition means for acquiring a plurality of condition indicators from the system at each of a plurality of times defining successive intervals of at most 1-sec duration, the condition indicators including (a) a plurality of vibration measurements or (b) one or more vibration measurements and one or more performance

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parameter measurements, processor means for constructing a condition signature for a present time from the condition indicators and for predicting, from condition indicators used to construct the condition signature for a previous time, a normal signature corresponding to a condition signature for a healthy system at the present time, comparator means for comparing the condition signature for the present time with the normal signature; and registration means for registering an event if the comparator for the present time indicates that the condition signature differs from the normal signature by more than a predetermined threshold, as recited in claim 18.

In the exemplary embodiments provided in the specification, the condition signature is based on the change in amplitude and the change in phase. Thus, the condition signature for the present time merges the values of the vibration amplitude at the present time and the vibration amplitude at the previous time (to obtain the change in amplitude), and the phase at the present time and the phase at the previous time (to obtain the change in phase). Therefore, the condition indicators used to construct the condition signature for the present time include the vibration amplitude at the present time and the phase at the present time.

The neural network predicts the corresponding normal signature. As shown in Figure 2, the prediction is based on the vibration amplitude, phase and speed at the previous time, and the speed at the next (*i.e.*, present) time. However, the first two of these quantities are condition indicators that have been used to construct the condition signature for the previous time. This example, therefore, provides basis for the amendments to the independent claims.

Further basis is provided by the Kalman filter example, which is discussed at page 19, line 11 to page 23, line 8. Note that in this example, both i and k are used to indicate time. The relationship between the two is that $i = k - 1$, *i.e.*, if i is the previous time then k is the present time.

Equation (3) on page 21 shows that the condition signature at time k, $y(k)$, is compared with the normal signature, $C\hat{x}\langle k \mid k - 1\rangle$. In this equation, $y(k)$ is a vector that

merges a set of condition indicators at present time k. However, the reference to $k - 1$ in the expression for the normal signature, $C\hat{x}\langle k \mid k - 1 \rangle$, indicates that the normal signature in equation (3) is based on values from the previous time, $k - 1$. As $Cx(i) + v(i)$ provides the normal signature at time i (see page 21, line 23), but $y(i) = Cx(i) + v(i)$ (see equation (1) on page 20), it follows that the normal signature in equation (3) is predicted from the condition indicators which were used to construct the condition signature at the previous time, $k - 1$.

Thus, in the Kalman filter example, all the condition indicators used to construct the condition signature for the previous time are used to predict the normal signature at the present time, which is consistent with and provides further basis for the requirement in the amended claims that the normal signature is predicted from condition indicators used to construct the condition signature for the previous time.

For the convenience of the Examiner, Applicants provide, attached, a copy of "A review of process fault detection and diagnosis" by Venkatasubramanian *et al.* (hereinafter "Venkatasubramanian") in *Computers and Chemical Engineering*, vol. 27, (© 2003), 293-311. Venkatasubramanian explains, in the first paragraph of subsection 5.2.1 on page 303, the type of approach used by Simani. Applicants call attention to the fact that the Venkatasubramanian paper is not prior art.

Also for the assistance of the Examiner, Applicants show respective schematic diagrams, labeled Figures A, B and C, illustrating the Simani approach and typical approaches of Applicants' claimed features.

Figure A illustrates the Simani approach as corresponding to Figure 3 of Simani, except that:

(a) each observer is a Kalman filter, which is the type of observer specifically described in Simani in the paragraph below Figure 3 at page 184, and

(b) the residuals, $e_m(t)$, produced by the Kalman filters are the inputs of a neural network trained to detect a fault in a particular process input sensor $u_1(t)$, as discussed in sections 4 to 6 of Simani.
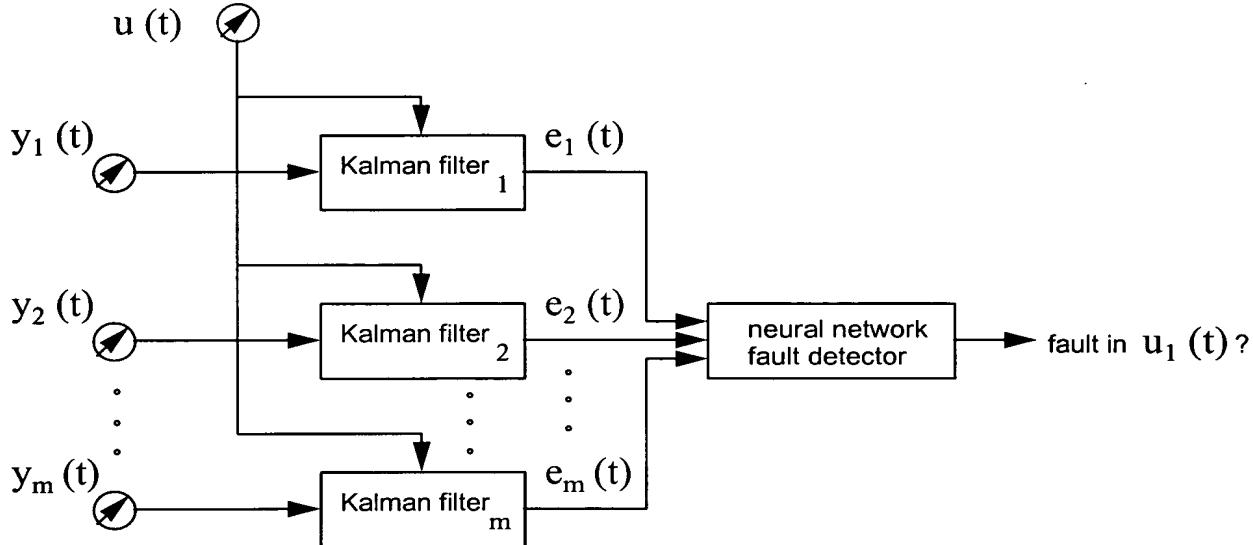

Figure A

Figure B, in contrast, illustrates the Kalman filter approach exemplified in the present application. To facilitate comparison with Figure A, where possible similar terminology has been used. Thus, t is time, and $y(t)$ and $y(t-1)$ are condition indicators for respectively the present and previous time. Figure B clearly shows the normal signature being predicted from condition indicators used to construct the condition signature for the previous time, which is consistent with Applicants' claimed features.
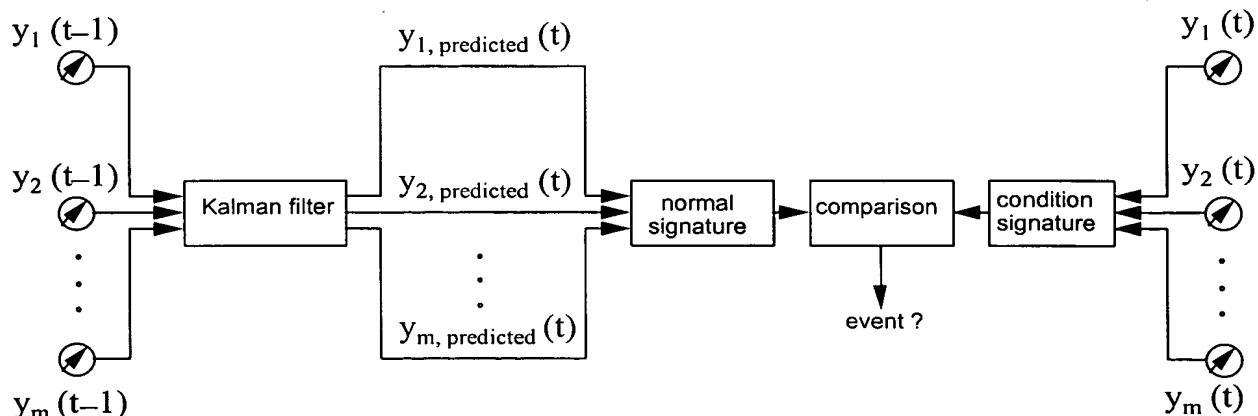
Figure B

Figure C illustrates the neural network approach exemplified in the present application. Again, to facilitate comparison with Figure A, where possible similar terminology is used. Consequently, t is time, u are system measurements, and $y(t)$ and $y(t-1)$ are condition indicators at respectively the present and previous times. In the particular neural network example discussed at page 18, line 6 to page 19, line 10 of the specification, system measurements u are shaft speeds at times t and $t-1$, respectively, and the condition indicators are the vibration amplitude and the phase.
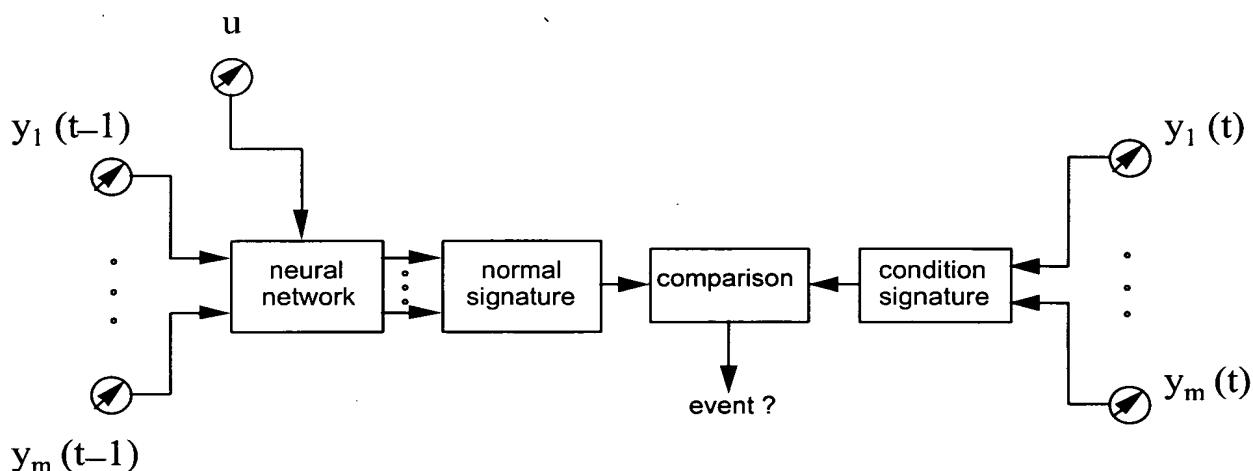
Figure C

Similarly to Figure B, Figure C shows the normal signature being predicted from condition indicators used to construct the condition signature for the previous time, as required by Applicants' claimed features.

Even a cursory examination of these illustrations shows that the approach of Figure A is very different to that of Figures B and C. In particular, Simani makes no use of information from the previous time, $t-1$. One reason for this is that Simani's neural network has nominally been trained to recognize all the possible faults to which the residuals $e_m(t)$ can relate, so it has no need for information from previous times during neural network testing. Thus the amendments to the claims provide further novelty over Simani.

As explained in February 3, 2004 Request for Reconsideration, to provide training data to encompass all possible departures from normality would be exceedingly difficult, and thereby counterintuitive, for a complicated system, such as a gas turbine. Thus, the claimed features provide a different approach, which is to predict a normal signature corresponding to the condition signature for a healthy system, and then to compare that normal signature with the actual condition signature. Such prediction and comparison does not require a model trained on data covering all possible departures from normality, but does need condition indicator data from the previous time. Thus, Simani fails to disclose all of the claimed features, and Applicants' claims are thereby patentable over Simani.

Applicants respectfully traverse the Examiner's response to Applicants' previous arguments. At page 6, paragraph 2, the Final Office Action asserts that Simani teaches constructing a condition signature at page 183, column 1, section 2, equation (1). However, Simani's equation is merely the standard and well-known Kalman filter equation, and has nothing to do with the construction of a condition signature, as provided in Applicants' claimed features. Figure 3 of Simani and Figure A above show each $y(t)$ being sent to a different Kalman filter rather than being merged or fused with the other $y(t)$ values. Thus, a condition signature, as exemplified in the specification (see page 3, lines 13 to 16), is never constructed by Simani.

In the paragraph bridging pages 6 and 7, the Final Office Action asserts that Simani discloses the difference between the condition signature and the normal signature at page 183, section 3, first and second paragraphs. Also, at page 7, paragraph 3, the Final Rejection asserts that Simani's equation (6) teaches predicting a normal signature. However, in both these instances Simani's equation (6) is misapplied or misinterpreted. This equation describes what happens as t tends to infinity, $i.e.$, in the steady state, in the absence of faults or measurement noise. Thus, $y_i(t)$ in Simani is <u>not</u> the condition signature; it is merely the i-th component of vector $y(t)$, $i.e.$, a single scalar value. Also, $y^i(t)$ in Simani is <u>not</u> the

normal signature; it is the estimate of the i-th component of vector y(t), which is again a single scalar value. Instead, equation (6) states that, in the steady state, a fault in the (single) i-th sensor will be detected by a non-zero value in the (single) i-th observer. That is, as Applicants explain at page 2, paragraph 2 of the February 3, 2004 Request for Reconsideration, Simani teaches a single observer per sensor. Each observer is associated with that one sensor, which has no association with comparing a condition signature with a normal signature.

Also in the paragraph bridging pages 6 and 7, the Final Office Action asserts that Simani discloses a neural network which performs the comparing and registering steps of Applicants' claimed features, and quotes extracts from page 184, section 4, first paragraph, and page 185, section 6, first paragraph. However, this misrepresents what Simani teaches in relation to the neural network. The two extracts from Simani quoted by the Final Office Action relate to distinct and temporally spaced phases of the use of the neural network. More specifically, the section 4 extract is concerned with using the neural network in test mode (i.e., detection of faults during operation), whereas the section 6 extract is concerned with training the network with example data.

In any event, if, as the Final Office Action apparently (and mistakenly) asserts, the residuals which output from Simani's Kalman filters are the difference between some kind of condition signature and normal signature, it would then be impossible for the neural network to compare the signatures. This is because the only inputs into the neural network are these residuals, i.e., the information needed to make a comparison between the signatures would not be available to the neural network because the signatures themselves are not input into the network.

At page 7, paragraph 5, the Final Office Action asserts that Simani teaches vibration measurements at page 184, section 5, first paragraph. Applicants respectfully disagree with the Final Office Action interpretation as being incorrect. None of angular position, and

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pressure at the compressor inlet, compressor outlet and turbine outlet is a vibration measurement. Vibration is generally recorded with a vibration transducer (*e.g.*, accelerometer), not a position or pressure transducer.

At page 7, paragraph 7, the Final Office Action asserts that Simani teaches constructing a prior learnt model predicting a normal signature at page 183, section 2, first paragraph. Equation (1) from this paragraph in Simani is merely the standard set of Kalman filter equations describing a linear dynamic process. The Final Office Action focuses on the second equation $y(t) = Cx(t)$, where C is a constant matrix of appropriate dimension obtained by means of modeling techniques or identification procedures. However, Simani does <u>not</u> teach constructing a prior learnt model predicting a normal signature. Simani merely states at page 185 at the end of section 5 that the "procedure used to transform the ARX input-output model into the state-space representation is available in literature." This is the only hint in Simani of how matrix C might be set. Reference [18], cited as the literature, is a book entitled *System Identification* by Söderström *et al.*, © 1987, and the Final Office Action has not shown how this volume provides the person of ordinary skill in the art with the prior learnt model approach of Applicants' claimed features.

Finally, having shown that the present independent claims are novel and inventive, the Examiner's comments in regard of the dependent claims are rendered moot.

A claim must be literally disclosed for a proper rejection under §102. This requirement is satisfied "only if each and every element as set forth in the claim is found, either expressly or inherently described, in a single prior art reference." See MPEP §2131. The Final Office Action has not satisfied this burden with Simani.

For at least these reasons, Applicants respectfully assert that independent claims 1, 8, 17 and 18 are patentable over the applied reference. The dependent claims 2-7, which depend from claim 1, and claims 9-16, which depend from claim 8, are likewise patentable over the applied reference for at least the reasons discussed as well as for the additional

features they recite. Consequently, all the claims are in condition for allowance. Thus,

Applicants respectfully request that the rejection under 35 U.S.C. §102 be withdrawn.

VI.   Conclusion

In view of the foregoing, Applicants respectfully submit that this application is in

condition for allowance. Favorable consideration and prompt allowance are earnestly

solicited.

Should the Examiner believe that anything further is desirable in order to place this

application in even better condition for allowance, the Examiner is invited to contact

Applicants' undersigned representative at the telephone number listed below.

Respectfully submitted,
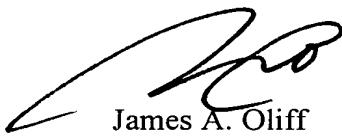
James A. Oliff
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JAO:GWT/gwt

Attachments:
      Copy of earlier filed PTO-1449 and stamped receipt
      English-language translation of EP 1 014 054 A2
      "A review of process fault detection and diagnosis" by Venkatasubramanian *et al.*

Date: June 16, 2004

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